EFFECTIVENESS OF PRESELECTION FOR CHILLING REQUIREMENT, PRECOCIOUSNESS, FRUIT DEVELOPMENT PERIOD, AND FRUIT QUALITIES IN PEACH AND NECTARINE (*Prunus persica* L. Batsch)

By

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TABLE OF CONTENTS

Page
ACKNOWLEDGEMENTS.......... ii

ABSTRACT.......... iv

SECTION I. INTRODUCTION.......... 1

SECTION II. LITERATURE REVIEW.......... 3

SECTION III. PRESELECTION FOR CHILLING REQUIREMENT AT THE SEED LEVEL.......... 14
Introduction.......... 14
Materials and Methods.......... 14
Results and Discussion.......... 17

SECTION IV. BREEDING FOR SHORT JUVENILE PERIOD.......... 28
Introduction.......... 28
Materials and Methods.......... 28
Results and Discussion.......... 29

SECTION V. THE HIGH DENSITY NURSERY SYSTEM (HDN) FOR BREEDING PEACH AND NECTARINE: A TEN YEAR ANALYSIS.......... 38
Introduction.......... 38
Materials and Methods.......... 39
Results and Discussion.......... 41

SECTION VI. SUMMARY AND CONCLUSSIONS.......... 58

LITERATURE CITED.......... 60

BIOGRAPHICAL SKETCH.......... 65

Abstract of Dissertation Presented to the Graduate School
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The peach and nectarine breeding program at the University of Florida uses a system called the High Density Nursery (HDN) for rapidly rearing seedlings to fruiting stage. An analysis of the progress obtained for several traits was undertaken to estimate the system degree of efficiency and provide insights into improvement of the system for future breeding.

Traits such as chilling requirement, fruit development period, and fruit size and color evaluated in the HDN showed high repeatabilities indicating that preselection for these traits is effective if done during the first fruiting year in the HDN. Traits such as fruit shape, and firmness and crop load were difficult to assess in the HDN. Progress in increasing fruit size has been achieved. Nectarines gained an average of 2.2 g per year from 1976 to 1984. Peaches showed an impressive gain of 3.7 g per year from 1975 to 1983; a decline in 1984 was due to selections with a shorter fruit development period resulting from embryo rescue. A sigificant positive correlation was found between fruit development period and fruit size (0.49**).

Attempts to select for chilling requirement based on seed chilling needs for germination proved to be of little value. A significant but low correlation was found (0.21**), which indicates that preselection based on chilling needs of individual seed is not practical, if the range in chilling explored is narrow.

Progress in selecting for precociousness should be obtained by intermating parents with heavy flower bud set. Crosses between heavy bud setters produced precocious progeny with high flower bud set. In 18-month-old-seedlings in the HDN the heritability value for flower bud set, calculated by midparent-offspring regression for this population, was 0.55.

SECTION 1

INTRODUCTION

Progress in breeding of fruit tree species is delayed mainly by the relatively long period for a plant to produce fruit and by the size of the plant (HANSCHE, 1983). These factors delay progress by reducing the genetic gain per year despite the high heritability for some traits. Approaches to overcome the influence of these factors include 2 methods intended to influence the length of the juvenile period. The first method includes grafting on dwarfing rootstocks, promoting vigorous growth, use of mature stocks for grafting of seedlings, and growth regulators. The second method permits the screening of large populations, such as the introduction of dwarfing genes into the breeding population (HANSCHE and BERES, 1980) and the use of the High Density Nursery system (HDN) for rearing trees (SHERMAN et al., 1973). These are the only methods available for screening larger populations in a reduced space. Plant generation time may also be reduced by breeding for short juvenile period (VISSER, 1976) but this alternative could take many generations to obtain substantial progress. Progress will depend on the intensity of selection applied to the breeding population.

This work explores the possibility of selecting for flower and leaf bud chilling requirement based on the chilling requirement of the seed for germination. The inheritance of flower bud set and its relationship to precociousness was studied in a representative sample of material used for nectarine and peach breeding.

Another objective of this research was to study the efficiency of selection in the HDN as a prescreening method in cultivar improvement. This study attempts to determine the effectiveness of evaluation for chilling requirement, fruit development period, crop load, fruit color, fruit firmess, fruit size and fruit shape in HDN in comparison with the same character expression on budded trees at field spacing.

SECTION II

LITERATURE REVIEW

Rapid genetic advance is possible only if a breeding program proceeds through succesive generations with reasonable dispatch. Progressive cultivar improvement depends on continual improvement of breeding stocks. This is accomplished by selecting and intermating in each generation only those individuals that show promise of producing superior progeny (HULL, 1952). Amount, rate, and cost of response to selection are important aspects to consider when conducting a fruit breeding program. A system of handling seedling populations that provides a rapid advance from seed to fruiting to increase genetic gain per year, minimizes nongenetic variation among seedlings, and is cost effective in raising a large number of seedlings would be very desirable (SHERMAN and LYRENE, 1983). Hansche (1983) pointed out that plant size and seedling juvenility are the major characteristics that impede progress in breeding fruit and nut species. He indicated that the removal of these roadblocks to cultivar improvement is what holds the greatest promise for significant genetic improvement.

The rate of response to selection (R) is the parameter that measures the progress of a breeding program. Response is generally measured by breeding cycle, and the time to complete a cycle depends on the length of the juvenile period and other factors such as selection criteria and mating system.

Much effort has been dedicated to shortening the juvenile period of plants. There appears to be a close relationship between plant height and the change in phase from juvenile to adult, although it is not possible to specify when this change occurs (ALDWINCKLE, 1975). The attainment of this phase change requires a minimum number of nodes before flowering will occur (ZIMMERMAN, 1972). Attainment of this number of nodes can be hastened by growing the plants under conditions conducive to rapid growth (VISSER, 1964; ZIMMERMAN, 1972; ALDWINCKLE, 1975). Constant high temperature, long photoperiod, heavy fertilization (especially N), and good pest control have been used to force growth of tree seedlings under greenhouse and field conditions. These methods have been succesful in cacao (TOXOPEOUS, 1969), citrus (CAMERON and FROST, 1968), fig (STOREY and CONDIT, 1969), crabapple (ZIMMERMAN, 1971), and peach (SHERMAN et al., 1973). In general, it has been found that within a progeny, seedlings that are more vigorous are likely to obtain the critical height in the shortest time. Other practices intended to reduce juvenility include girdling, pruning, grafting on mature stocks, and use of growth regulators. These practices have been attempted in many crops but rarely have been effective (ZIMMERMAN, 1972; SHERMAN AND LYRENE, 1983). Extensive reviews of the phenomena of juvenility and flowering in woody plants have been made (ZIMMERMAN, 1972) as well as the practices used to hasten the onset of flowering (SHERMAN and LYRENE, 1983).

Apart from the effect that cultural practices have on the juvenile period, the within and between progeny differences are due to heredity. In apple, some parents contribute to a very short juvenile period, with many of their seedlings flowering in 3 or 4 years from germination.

Others may contribute to very long juvenile periods, e. g. 'Northern Spy' whose progenies may take 10 or more years to fruit (BROWN, 1975). Visser (1965, 1970) provided objective, quantitative evidence that considerable variation exists in apple and pear for length of juvenile period. In a further study, Visser (1976) showed that, in the population he studied, the genes influencing this trait are primarily additive. Visser (1965) found a good correlation (0.77 at n=42) between the length of the period elapsing between grafting and first-bearing of the parents and the length of the juvenile period of their progeny. This implies that seedlings of late bearing parents would inherit 2 undesirable characters as they probably come late into bearing both in the juvenile and the propagated adult phase. A significant negative correlation between the duration of the juvenile period and the vigor of the seedlings as measured by trunk diameter was reported for pear and apple seedlings by Visser (1964). He suggested that by selecting the more vigorous seedlings and discarding the weaker ones the breeder is also selecting for short juvenile period and consequently for precociousness. Recently Shen et al. (1982) found no correlation between those traits in progenies of 11 crosses of pear. Also, when considering triploids and tetraploids in apple, different standards must be applied. In general, the polyploids have much longer juvenile periods; however the seedlings may attain greater size than diploids (BROWN, 1975).

There appears to be genetic variability for precocity in cherries (FOGLE, 1961), pears (ZIELINSKI, 1963), pecans (MADDEN, 1968), and apples (BROWN, 1975). Hansche (1983) suggested that mass selection should be effective in genetically reducing the length of the juvenile period. He used Visser's data (VISSER, 1976) and indicated that one could reasonably expect an average reduction in the juvenile period of between 10 and 14 months in a single selection cycle.

Breeding for precocity may not only increase breeding efficiency, but precocity may have an additional advantage in commercial production because of the general relationship between short juvenile period and early bearing of grafted trees (VISSER, 1965) and between precociousness and heaviness in fruit yield (MADDEN, 1968).

Rate of response to selection (R) is dependent on factors expressed in the formula $R=Sh^2$, where S is the mean phenotypic value of the individuals selected as parents expressed as a deviation from the population mean (selection differential) and h^2 is the heritability of the trait. The selection differential can also be expressed as iSp where i=selection intensity and Sp is the phenotypic standard deviation for the trait under study (FALCONER, 1982). Then the expected R becomes $R=ih^2Sp$. In order to have an increase in R, the S factor must be increased, but this implies an increase in the number of seedlings from which to select. In fruit tree species where large plants are expected, this becomes difficult because the cost to raise larger plants is also increased.

One method for increasing the number of plants screened in the same area is to introduce dwarf genes into that population. Hansche et al. (1979), by introducing the dw/dw genes into peach populations, has been able to plant 10 times the density used for standard genotypes. Genes which induce short stature are widespread in nut and tree species (DECOURTYE, 1967; KESTER and ASSAY, 1975; SOOST and CAMERON, 1975; ALSTON, 1976). Decourtye (1967) investigated the inheritance of dwarfness in apple, which appears to be the same as the compact type (spur type). All dwarfs need not necessarily be spur types. His results showed that the dwarf character was controlled by a single recessive gene and that a number of cultivars including 'Golden Delicious' were heterozygous for this trait. Spur types which have been used in breeding do not all behave in the same way (LAPINS, 1963). He suggested that some of the mutants are chimeras. In sweet cherries dwarfness is recessive and is controlled by relatively few factors (FOGLE, 1961). It appears possible to introduce dwarfing genes in the breeding lines of many fruit species and apply a more rigorous selection pressure by increasing the number of seedlings to be screened.

Another method that has proven to be efficient in producing new cultivars of peach and nectarine is the one described as the HDN (SHERMAN et al., 1973). This system allows up to 50 times the density of previous seedling plantings and over 300 times that used in standard production plantings. Similar densities have been used for blueberry seedlings. Emphasis in peach has been given to selection for fruit color, shape and firmness. Approximately 55% of all peach seedlings grown in the HDN fruited the second year after seed was harvested. The normal cycle to first significant fruiting is 5 years. The HDN system has been reviewed by Hesse (1975), who stated that the close planting would not allow adequate bearing surface for fruit evaluation and that it is not suitable for quantitative genetic studies because the density would not allow normal growth and development for many of the traits such as tree shape and yielding ability.

Heritability (h^2), which expresses the amount of genetic determination of a trait, is influenced by the environment; the greater the environmental effects, the lower the heritability of the trait. This provides considerable motivation to breeders for reducing the effects of environmental variation on measurements of important traits. There are 4 ways this might be done: by reducing the variation in the environment in which the plants are grown, by improving measurement techniques, by estimating the effects of environment and adjusting accordingly, and by replicating measurements (HANSCHE, 1983). Heritability of means of replicated measurements (n) generally will be greater than h^2 of individual measurements, but repeating measurements extends the length of selection cycles. Results of a number of studies in fruit and nut species have shown that R generally decreases for n greater than 2 (SCHULTZ, 1955; HANSCHE and BROOKS, 1965). Hansche et al. (1966) gave statistical procedures to eliminate or compensate for the effects of yearly differences in climate on some traits that are highly affected by the environment such as bloom time and ripening dates. Estimates of h^2 in fruit plants have proven to be of value only on those traits where the measurement scales were well established (BRINGHURST, 1983).

The first problem when measuring R arises from the variability of generation means. Inspection of any graph of selection shows that the generation means do not progress in a simple, regular fashion. The consequence of this variation between generation means is that R can seldom be measured with accuracy until several generations of selection have been made. The best measure of average R per generation is then obtained from the slope of a regression line fitted to the generation means (FALCONER, 1982).

The variation in generation means can be due to random drift, sampling errors, differences in selection differential, and environmental factors. Response can be used as a means to estimate the h^2 in the base population because the expected value of the ratio R/S is h^2. The heritability estimated in this way is called realized heritability and does not provide a valid estimate of the h^2 in the base population if there are systematic changes due to environmental trends or inbreeding. Valid estimates of h^2 in the narrow sense can be obtained using the regression of offspring on mid-parent values, provided that there is no non-genetic cause of resemblance between offspring and parents (FREY and HORNER, 1957).

Prescreening of seedlings reduces the cost of growing plants longer and concentrates earlier efforts on those plants that may have some potential for future use. Correlations between traits when the plants are juvenile and when they mature permits a rapid screening for some traits. For example, screening for thornlessness in adult raspberry canes can be determined at the seedling stage by looking for stalked glands on the cotyledon (KNIGHT et al., 1964). Rabbiteye blueberry seedlings that had non-waxy green foliage as small plants later produced black fruits (BRIGHTWELL et al., 1955), and peach seedlings with a short flowering to ripening interval can be selected before fruiting because the trait is highly correlated with red anthocyanins developing in senescing leaves of one year-old seedlings (SHERMAN et al., 1972; VILEILA-MORALES et al., 1981). In addition, foliage color and fruit color are correlated in pear (LAYNE and QUAMME, 1975), leaf pH of 2 year old apple seedlings was found to be sufficiently related to fruit pH, measured when seedlings were 6 to 7 years old (VISSER and VERHAEGH, 1978), and leafing date is correlated to blooming date in walnut and apple (TYDEMAN 1958, 1964; FORDE, 1975).

High correlations between observed traits in the same genotype at different times during the life of the seedling provide an effective method to discriminate seedlings for further use as parents or potential cultivars. The effectiveness of this procedure depends largely on the methods used to evaluate the traits. When more than one measurement of the character can be made on each individual, the phenotypic variance (VP) can be partitioned into variance within individuals (VWI) and between individuals (VBW), and the ratio of the VBW to the total VP is the intraclass correlation (r). This is the correlation between repeated measurements of the character in the same individual and is known as the repeatability of the character. The main uses of r are to show how much can be gained by the repetition of measurements, to set upper limits to the ratios VG/VP (broad sense heritability) or VA/VP (narrow sense heritability), and to predict future performance from past records (FALCONER, 1982).

Kester et al. (1977a) indicate that for some traits of almond kernel, the first 2 years of observation were enough to provide good estimates, and they showed high h^2 values. Some traits such as hull dehiscence showed zero h^2. This was probably a result of inadequate measurement procedures, such as harvesting the fruit from the offspring before they were completely mature in contrast to fruit from parents which was often harvested at a later time from established trees.

Commonly, quality factors represent more problems to evaluate and therefore the estimates are highly variable within a given genotype. Adequate procedures and equipment to evaluate quality factors are still difficult to integrate into fruit improvement programs (MOORE, 1983).

Breeding fruit tree species in areas of mild winter often requires the use of germplasm exhibiting a wide variation in chilling requirement (CR). Selection for CR is necessary and in some progenies the amount of seedlings with the proper bud CR for the areas intended represents about 50 to 60% of the total number evaluated (W. Sherman, 1984 pers. comn.). Many of the remaining plants never produce fruit for evaluation due either to the delayed bloom resulting from lack of chilling or to frost damage resulting from too early blooming. Most woody species of the temperate zone require a certain amount of chilling for breaking dormancy in the spring. Their seeds also require moist chilling to germinate, the amount of which has been associated with the amount of chilling required for the buds (WESTWOOD and BJORNSTAD, 1968; PASTERNARK and POWELL, 1980; CHANG and WERNER, 1984).

Westwood (1978) has suggested that the mechanisms controlling CR in buds and seeds may be similar. He suggested based on his experience with pear, that an easy way to screen for an individual seedling with low bud CR is to give a limited amount of chilling to many genetically diverse seeds and those that germinate will produce plants with a bud CR related to the chilling needed to for seed germination. Significant positive correlations have been found between the CR of the seeds for germination and the bud CR of the seed parent in several species (WESTWOOD and BJORNSTAD, 1968; KESTER, 1969; PASTERNARK and POWELL, 1980; CHANG and WERNER, 1984). However, differentiation between lines exhibiting small differences in CR (less than 300 hours) was not possible (CHANG and WERNER, 1984)

Kester (1969) found that CR was not significantly different in seed populations resulting from reciprocal crosses involving cultivars of long and short chilling needs. Abscisic acid (ABA) evolution in seeds under stratification indicates that the levels of ABA remain basically the same in the seed coat and cotyledons but decreases in the embryonary axis (WONG 1971, cited by BONAMY and DENNIS, 1977), indicating that the role of seed coats in seed germination is more of a physical nature than a chemical one.

Relationships among blooming and leafing dates of parents and offspring, and the CR of the intervening seeds were determined in a group of almond families (KESTER et al., 1977b). Heritability estimates from parent-offspring regressions for blooming and leafing dates were high. The correlation of seed chilling values to the bloom index of the resulting plants was high when family means were compared, but low when when the indexes of the individual plants were compared. The high h^2 of leafing and blooming found in this study suggests additive gene action, similar to those reported in other fruit crop breeding populations (HANSCHE et al., 1966; HANSCHE et al., 1972). Mutations modifying bloom date have occurred in almond, suggesting that some major genes might be exerting an influence on time of bloom (KESTER and ASSAY, 1975). Grigorian (1975) reported similar results for pollen effects in almond cultivars of different blooming dates; however, he found exceptions to a strictly additive relationship. Certain late blooming cultivars produced seeds with low CR and Grigorian attributed this fact to the difference in the heat requirement of those cultivars for blooming. Early selection for time of bloom on the basis of leafing time appears to be more useful for individual plants than the seed chilling index (TYDEMAN 1958, 1964; OPPENHEIMER and SLOR, 1968). It appears that different genetic systems control bloom, leafing, and germination. There appears to be little variation in peaches for the number of heat units necessary to force flowering after CR is satisfied. This is evidenced by the short bloom period (3 to 5 days) in temperate zones where all cultivars are supersaturated with winter chilling. Thus, main differences in time of bloom are not attributed to variability in heat units but to chilling units.

SECTION III

PRESELECTION FOR CHILLING REQUIREMENT AT THE SEED LEVEL

Introduction

Breeding fruit tree species for mild winter areas often requires use of germplasm exhibiting a wide variation in chilling requirement (CR); therefore, selection within a progeny for CR for a particular area is necessary. In some progeny the frequency of plants with the proper CR is about 50 to 60% of the total number of plants screened. The separation of germinating seed into chilling requirement classes would permit seedlings to be sent to the proper areas for growth and evaluation. Thus, a saving of time and money would result because non-adapted seedlings would not have to be grown in a given area.

Materials and Methods

The possibility of selecting for bud CR at the seed level was investigated by using crosses and open-pollinated (OP) families from 16 selections and cultivars of peach and nectarine from the University of Florida fruit breeding program. Two pollen parents 'EarliGrande' (200 chilling units) and Fla. 7-3 (400 chilling units) were crossed with 16 seed parents (Table 3.1). Crosses were made during February and March of 1982. Flowers were hand pollinated with fresh pollen of the current season. Attempts were made to obtain approximately 25 seeds from each cross. Fruit from crosses and OP families were harvested when ripe, their pits were cracked, and the seeds were put into the refrigerator for stratification. The seeds prior to stratification were soaked in a Captan (N-[(trichloromethil)thio]-4-cyclohexene-1,z-dicarboximide) solution (2 g/liter) for 5 minutes and placed in plastic bags filled with perlite previously treated with the fungicide Captan. No rotting problems during stratification were detected. The temperature of the refrigerator was kept within the range of 5 to 6 C. An additional group of 10 families including OP and crosses were included in this study, but their seed coats were removed. The purpose of this treatment was to test if by removing the seed coat a higher correlation could be obtained between embryo CR and the resulting seedling CR. Previous reports (LIPE and CRANE, 1966; DIAZ and MARTIN, 1972; DU TOIT et al., 1979) indicate the presence of germination inhibitors in peach seed, which serve to lenghten the CR of the embryo. Removal of the seed coat is reported to promote faster germination of peach seed (BONAMY and DENNIS, 1977; CHANG and WERNER, 1984).

Seed lots were examined every 5 days once they started germinating. Individual seeds were taken out of the bag when the radicle reached a length of between 2 and 2.5 cm. The number of chilling units for germination of each individual seed was recorded. One hour in the refrigerator was counted as a chilling unit. The germinated seeds were placed in flats containing fumigated soil and grown in a greenhouse until they reached between 25 and 30 cm height. The seedlings were planted in the field in late September of 1982 at a spacing of 1 m between rows and .2 m within rows. The management of this high density nursery (HDN) was as specified by Sherman et al. (1973).

The seedlings were classified for their chilling needs by time of bud break in February and March of 1984. The method employed was to use for reference cultivars of known bud CR. Those reference cultivars were 'Okinawa' 150 units, 'Sunred' 250 units, 'Early Amber'350 units and 'Sunlite' 450 units. Subclasses were generated to estimate seedling bud break at 25 unit increments of CR. Chill units of parents were estimated relative to each other based on time of bud break. Time of bloom under north central Florida conditions is mainly dependent upon CR completion rather than on differences among seedlings for heat unit accumulation; therefore CR of seedlings was considered relative to the date when most of the flower buds were open (>75%) based on comparisons with previously defined selections or cultivars.

The SAS package provided computational procedures to analize for correlations, regressions, and contrast tests. The general linear model (GLM) procedure was used to obtain regression coefficients (b) as a measure of narrow sense heritability (h^2) when a mid parent-offspring regression was analyzed. In cases where the number of offspring per family was different, a weighted regression (by n) was performed (FREUND and LITTELL, 1981).

Results and Discussion

Relationship Between Mid-Parent CR and Seed CR. A low nonsignificant correlation was found (0.08) between CR of the parents and the CR of their seeds (Figure 3.1 and Table 3.2). The chilling needs for the 10 families without seed coat was 2160 units as compared to 2510 units required to germinate seed of the same 10 families with the seed coat still present. As can be seen in Table 3.2 the seed coat removal did not improve the correlation with mid-parent CR for bud break values in any regular pattern. However, removal of seed coat slightly reduced the time in stratification needed for germination. At the bottom of Table 3.2 is 'Redhaven', a higher chilling cultivar (950 units of CR). When 'Redhaven' was included in the analysis a significant and positive linear correlation between mid-parent CR and seed CR (family) was found (r=0.43 **).

The range of mid-parent CR units was between 262 and 450 chilling units as shown in Table 3.3. The narrow range in parent and progeny CR may be the main reason why we did not find a significant correlation between mid-parent CR and progeny CR as reported by other researchers (WESTWOOD and BJORNSTAD, 1968; CHANG and WERNER, 1984). There was no correlation between bud CR of mid-parent and CR of their seeds to germinate among the Florida germplasm (Figure 3.1). The inclusion in the analysis of 'Redhaven' expanded the range in CR in the experiment and consequently a highly significant r value was obtained. This finding substantiates the study by CHANG and WERNER (1984) which indicates that it is difficult to separate breeding lines that differ in less than 300 units of CR.

Effects of Pollen Parent on Seed and Resulting Seedling Bud CR. Because only 2 parents of different chilling needs were used in this study it was decided to determine if a relationship could be established among the CR of the parent on seed and bud CR of their progeny. The effect of the pollen parent on the CR of their seeds for germination was not significant statistically, as compared to the pollen parent effect on CR of their seedlings (Table 3.4). In general, crosses with 'EarliGrande' (200 units of CR) produced lower chilling progeny as compared to those resulting from crosses with selection Fla. 7-3 (400 units of CR). The regression of mid-parent values on offspring means in Figure 3.2 gives an indication of additive gene action ($h^2 = 0.49$) for inheritance of this trait. The $h^2 = 0.49$ is conservative and probably should be higher, considering the range in CR of the material used. Again the inclusion of 'Redhaven' in the regression analysis inflated the h^2 value to 0.75. This experimental evidence suggests that the phenomena of seed CR and bud CR are not as closely related as has been suggested (WESTWOOD, 1978), especially when a relatively narrow range of chilling parents and progeny is being considered.

Relationship Between Individual Seed CR and Corresponding Seedling CR. When individual seed CR was correlated to its corresponding seedling CR, a low significant positive correlation of (0.206**) was obtained (Table 3.5). This low correlation value may be due to the fact that a wider segregation for CR occurred in seedlings than in their hybrid parents. The range in CR for the seedlings was from 100 to more than 450 units, in contrast to the range of of 250 to 450 units of mean family values. The removal of the seed coat did not prove to be of value in increasing the correlation, although a higher correlation was expected by removing the maternal influence of the seed coat. Indications that the role of the seed coat in germination is more of a physical nature than a chemical one can be drawn from the data presented by several authors (KESTER, 1969; WONG, 1971 cited by BONAMY and DENNIS, 1977; CHANG and WERNER, 1984). The low correlation values obtained in this study between seed CR and that of its corresponding seedling CR for bud break agree with those obtained by KESTER et al. (1977b) in almond progenies (0.129) but the values reported for family mean comparisons are completely different. Early selection among seedlings for CR on the basis of CR for seed germination does not appear practical in narrow based populations for this trait. It is not clear if the same trend will occur when hybrids between parents representing wider ranges in CR are crossed. Early selection for time of bloom has been carried out efficiently on the basis of leafing time in apple (TYDEMAN 1958, 1964; OPPENHEIMER and SLOR, 1968). Early selection in apple is especially useful because the time between first leafing and first bloom may be several years. Even though the juvenile period of peaches is relatively short, screening for time of bloom could probably be done during the first leaf in the high density nursery if plants big enough are available.

Table 3.1. Florida low chill selections and cultivars used as seed parents.

Seed parent	Chilling requirement (units)
Fla. 3-4	375
Fla. 9-18	375
Fla. 5-20	325
Fla. 9-9	350
Fla. 7-11	375
Fla. 5-15	350
Fla. 9-16	325
Fla. 9-12	300
Fla. 5-14	350
Fla. 9-13	350
Fla. 8-6	350
Fla. 8-14	350
Flordagold	300
Sunripe	350
Sunlite	450
Fla.KE15	400

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Fla. 7-11	375
Fla. 5-15	350
Fla. 9-16	325
Fla. 9-12	300
Fla. 5-14	350
Fla. 9-13	350
Fla. 8-6	350
Fla. 8-14	350
Flordagold	300
Sunripe	350
Sunlite	450
Fla.KE15	400

Table 3.2. Relationship between mid-parent bud chilling requirement (CR) and amount of chilling for 80% germination in seed with and without testa in several Florida low chill peach and nectarine families.

Family	Estimated midparent CR (units)	Chilling units	
		with testa	without testa
Fla.5-20 x EG	262	2448	2184
Fla.9-9 x EG	275	2496	2280
Fla.KE15 x EG	300	2496	2184
Fla.9-12 OP	300	2400	----
Flordagold OP	300	2424	----
Fla.5-15 OP	325	2712	2160
Fla.9-16 OP	325	2448	----
Sunripe OP	350	2232	1872
Fla.9-9 OP	350	2592	----
Fla.3-4 OP	350	2664	----
Fla.5-14 OP	350	2568	1944
Fla.9-18 OP	375	2112	----
Sunlite OP	400	2784	2328
Fla.KE15 OP	400	2592	2136
Fla.KE15 X 7-3	400	2496	2472
Sunlite x 7-3	425	2496	1824
Redhaven OP^{z}	950	3840	----
		r=0.08^{y} n.s.	r= -0.14^{x} n.s.

z not included in correlation analysis for the value shown
y correlation value for n=48
x correlation value for n=10
EG ='EarliGrande'
7-3 = Fla. 7-3

Table 3.3. Estimated bud chilling requirement (CR) of mid-parent and offspring in some Florida low chill peach and nectarine families.

Cross	mid-parent	progeny mean	S D	progeny range
Fla.3-4 x EG[z]	275	310.18	86.67	175 - 475
Fla.3-4 x 7-3[y]	375	401.66	42.51	300 - 475
Fla.3-4 OP	350	359.61	65.22	150 - 475
Fla.9-18 x EG	287	352.50	90.28	175 - 475
Fla.9-18 x 7-3	387	423.07	45.78	350 - 475
Fla.9-18 OP	375	397.72	62.70	275 - 475
Fla.5-20 x EG	262	371.87	16.02	350 - 400
Fla.5-20 x 7-3	362	355.35	48.76	250 - 450
Fla.5-20 OP	325	355.00	20.83	300 - 400
Fla.9-9 x EG	275	322.36	68.96	175 - 450
Fla.9-9 x 7-3	375	402.97	43.54	275 - 475
Fla.9-9 OP	350	362.75	22.89	250 - 450
Fla.7-11 x EG	287	316.66	53.17	250 - 375
Fla.7-11 x 7-3	387	354.34	84.15	175 - 475
Fla.7-11 OP	375	347.72	93.51	100 - 450
Sunripe x EG	275	320.83	58.31	250 - 400
Sunripe x 7-3	375	367.85	51.32	275 - 475
Sunripe OP	350	379.46	25.50	350 - 450
Fla.5-15 x EG	262	339.77	95.94	175 - 450
Fla.5-15 x 7-3	362	359.37	76.30	175 - 450
Fla.5-15 OP	325	375.00	96.95	175 - 475
Fla.9-16 x EG	262	296.62	54.69	175 - 375
Fla.9-16 x 7-3	362	394.50	51.33	250 - 475
Fla.9-16 OP	325	384.48	33.68	350 - 450
Fla.KE15 x EG	300	390.62	70.63	175 - 475
Fla.KE15 x 7-3	400	389.77	95.32	175 - 475
Fla.KE15 OP	400	365.78	100.76	150 - 475
Sunlite x EG	325	358.85	57.30	250 - 475
Sunlite x 7-3	425	428.22	42.20	350 - 450
Sunlite OP	450	364.28	47.07	250 - 450
Fla.9-12 x EG	250	304.16	89.08	100 - 450
Fla.9-12 x 7-3	350	387.50	56.39	275 - 475
Fla.9-12 OP	300	345.83	31.68	275 - 400
	r=0.56 **[x]			

z EG= 'EarliGrande' chilling req.=200 units

y 7-3 = Fla.7-3 chilling req.= 400 units

x correlation value for n= 48

Table 3.4. Effect of pollen parent on seed chilling requirement (CR) for germination and resulting seedling CR.

Pollen sources contrasted	Characteristics of progeny			
	Seed CR (units)[z]	F value	Seedling CR (units)	F value
'EarliGrande' vs Fla. 7-3	2172 vs 2278	(2.91^{ns})	335 vs 377	(9.91**)
'EarliGrande' vs OP	2172 vs 2304	(1.86^{ns})	335 vs 366	(18.11**)
Fla. 7-3 vs OP	2278 vs 2304	(0.35^{ns})	377 vs 366	(9.59**)

z average of 12 families per cross or OP.
ns, **= non significant and significant at P=0.01 respectively.

Table 3.5. Correlation between chilling requirement (CR) of seed and bud break in seedling and seed families in the Florida low chill peach and nectarine population.

Comparison	n	Correlation coefficient (r)
Mean CR of parents vs CR of seeds	48^z	0.08 n.s.
Mean CR for parents vs mean CR of their offspring	48^z	0.56**
Mean seed CR (family) vs family bud CR	36^z	0.005n.s.
Individual seed CR vs individudual seedling CR (with seed coat)	943^y	0.206**
Individual seed CR vs individual seedling CR (no seed coat)	226^y	-0.083n.s.

z number of families
y number of seedlings
n.s., ** = nonsignificant, and significant at P=0.01, respectively

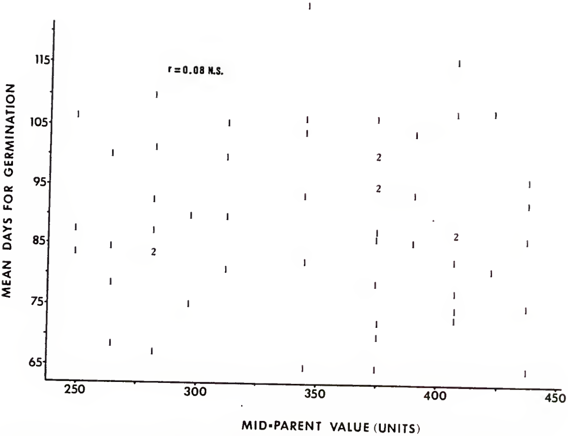
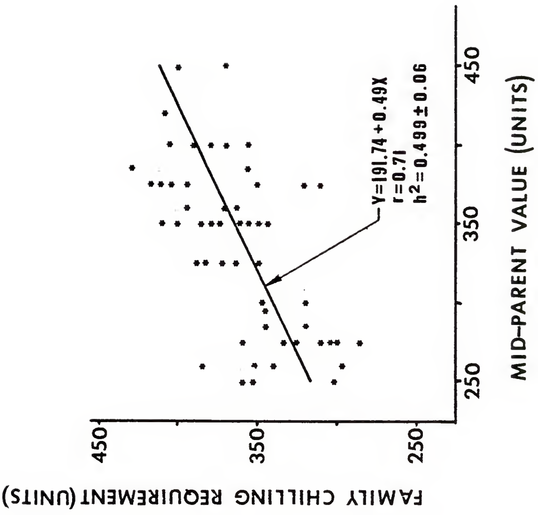


FIGURE 3.1. Relationship between midparent value for bud chilling requirement and family mean days for seed germination under stratification.

FIGURE 3.2. Regression of offspring on Mid-parent value for bud chilling requirement in some low chill Florida selections.


Y=191.74+0.49X
r=0.71
h2=0.499±0.06
250
350
450
MID-PARENT VALUE (UNITS)
450
350
250
FAMILY CHILLING REQUIREMENT(UNITS)

SECTION IV

BREEDING FOR SHORT JUVENILE PERIOD

Introduction

Seedlings of most woody plants pass through a juvenile phase during which they cannot be induced to flower. The delay in flowering caused by a long juvenile period may last several years and is one of the major problems limiting genetic advance under selection in most breeding programs (HANSCHE, 1983). The juvenile phase can be shortened considerably in some species by genetics, controlling the environment, application of growth regulators, and by various cultural practices (ZIMMERMAN, 1972). Early selection for precocious seedlings would best shorten the breeding cycles and improve the speed of producing cultivars.

Materials and Methods

Crosses using 'EarliGrande' (a light flower bud setter) and Fla. selection 7-3 (a heavy flower bud setter) as pollen parents were made in February and March of 1982. Twelve selections and cultivars with varying degrees of flower bud set were used as seed parents. The 12 open pollinated (OP) families were also included in this study because peaches are reported to be highly (95%) self-pollinated. Seeds from crosses and the resulting seedlings were handled as described in Materials and Methods in section 3.

Flower bud set was evaluated when the seedlings were 18 months old. The scale used to evaluate flower bud set was from 1 to 10; 1 the lowest to 10 = complete flower bud formation in most of the nodes of terminal branches. Flower buds were easy to distinguish from vegetative buds due to their difference in size and shape. The time of the year for evaluation was during bud swell. Parents which were in an adjacent block and managed as a commercial planting were also scored using the same criteria.

Seedling plant vigor was evaluated as trunk diameter during bloom time, at a height of 0.5 m.

Flower bud set, trunk diameter, and percent flowering plants were analyzed for correlations. Offspring mid-parent values were regressed using a weighted regression procedure to obtain estimates of narrow sense h^2 for flower bud set. Estimates of genetic variances and contrast test were done by using the general linear model (GLM) procedure.

Results and Discussion

The possibility that the length of the juvenile phase of a peach or nectarine seedling could be related to its vigor (as measured by trunk diameter) was investigated. The correlations between trunk diameter and flower bud set ($r = 0.29$) and between trunk diameter and percentage fruiting plants (r =0.03) were nonsignificant, indicating that flower bud set has a separate major genetic component that is unrelated to plant vigor (Table 4.1). The finding that trunk diameter is not related to flower bud set rating does not agree with the observations of Visser (1964) in apple and pear. Shen et al. (1982), however, reported that there were nonsignificant negative correlations between trunk diameter and length of the juvenile period in pear progenies. Amount of growth and length of the juvenile period appear to be independently inherited characters and selection for short juvenile period cannot be reliably based on trunk diameter. The case of polyploids in apple supports this idea in that triploids and tetraploids tend to have longer juvenile periods than diploids even though they may be more vigorous and attain greater size at an earlier age (BROWN, 1975). Thus, the juvenile period appears to be negatively correlated to tree vigor only within a particular line.

The average number of fruiting plants per family is correlated with the average rating of flower bud set per family (0.38**). This indicates that plants which formed flower buds had buds strong enough to set fruit, and indicates that flower bud set can be evaluated in the high density nursery during the first fruiting year.

Inheritance of Flower Bud Set. The estimate of narrow sense heritability was 0.54 for the families under study and indicates mainly additive gene action (Figure 4.1). This estimate is reliable for this population but would be conservative where selection for precociousness has not been practiced. Some selection for precociousness has been done in this breeding population, in that plants not producing fruit in their second or third leaf in the fruiting nursery are usually discarded. This is evident in Table 4.2 which shows that the range of seed parents in relation to bud set goes from 5 to 10 in the scale used, while the bud set range in the offspring often ranges beyond one or both parents.

Influence of Pollen Parent on Flower Bud Set. Crosses with 'EarliGrande' as male parent consistently produced progenies with lower flower bud set rating (Table 4.2) as compared with crosses involving Fla. selection 7-3. 'EarliGrande' crosses averaged 1.8 compared to 4.0 for Fla. 7-3 crosses (Table 4.3). Furthermore OP families (mostly self pollinated) were significantly different from crosses performed with either male parent (Table 4.3). These results confirm previous findings in other species (FOGLE, 1961; ZIELINSKI, 1963; MADDEN, 1968; VISSER, 1976), in the sense that some crosses may produce progenies with half or twice the normal juvenile period. The present study was conducted under the HDN where the plants have a strong competition with each other for light, water, and nutrients due to the high plant density (about 50,000 plants/ha); thus the expression of precociousness under these conditions is probably determined more by genetic than by enviromental factors. Otherwise families with larger plant size as measured by trunk diameter which attained the suppossedly minimum number of nodes for flowering (ZIMMERMAN, 1972) would have been expected to flower more heavily than families with smaller plant size.

This study suggests that the degree of bud set in mature trees influences the number of precocious seedlings in their offspring besides influencing the number of flower buds. Crosses made between normal and dwarf genotypes with short internodes have been shown to produce precocious seedlings (Ralph Scorza, 1984 per. com.). Dwarf peaches have short internodes and are usually heavy bud setters, and short internodes in peach are reported to be associated with heavy flower bud set (BLAKE, 1943).

Similar correlations have been reported in apple by Visser (1965). He found a strong correlation between the length of the juvenile period of the progenies and the length of the vegetative period of the parents (period elapsing between grafting and first bearing).

Even though heavy flower bud set is not critical to obtain adequate yields in peaches and nectarines, the use of heavy bud setters as parents could prove to be advantageous to speed up the breeding process by producing higher percentage of progeny to fruit in 2 years. Discarding of seedlings that do not flower in their first year under the fruiting nursery will eventually increase the amount of seedlings bearing and therefore would allow a strong selection pressure for other characters. The high h^2 value obtained indicates that simple recurrent selection should lead to rapid progress in selecting for precociousness.

Table 4.1. Phenotypic correlation matrix among flower bud set, trunk diameter, and fruiting plants in Florida low chilling peach and nectarine seedlings.[z]

	Trunk diameter	Fruiting plants(%)
Flower bud set	-0.29 n.s.	0.39 **
Trunk diameter	---------	0.03 n. s.

---

z correlation between family means n=36.

n.s.,* = nonsignificant and significant at P=0.05, respectively

Table 4.2. Flower bud set of mid-parents and their offspring in some low chill Florida peach and nectarine families.

Cross	Mid-parent value[z]	N	Progeny mean[y]	SD	Progeny range[y]
Fla.3-4 OP[x]	10.0	27	5.53	1.79	3 - 9
Fla.3-4 X EG[x]	7.5	30	2.00	0.91	1 - 4
Fla.3-4 X 7-3	10.0	26	6.10	2.27	1 - 9
Fla.9-18 OP	9.0	11	2.36	1.74	1 - 6
Fla.9-18 X EG	7.0	20	2.36	1.18	1 - 6
Fla.9-18 X 7-3	9.5	26	3.23	2.12	1 - 10
Fla.5-20 OP	5.0	20	2.55	1.73	1 - 7
Fla.5-20 X EG	5.0	8	1.25	0.46	1 - 2
Fla.5-20 X 7-3	7.5	28	3.25	1.66	1 - 7
Fla.9-9 OP	10.0	49	2.57	1.59	1 - 9
Fla.9-9 X EG	7.5	38	1.71	0.92	1 - 4
Fla.9-9 X 7-3	10.0	42	4.73	1.97	1 - 9
Fla.7-11 OP	7.0	22	4.09	2.34	1 - 7
Fla.7-11 X EG	6.0	15	1.71	0.92	1 - 4
Fla.7-11 X 7-3	8.5	23	5.39	2.38	1 - 10
Sunripe OP	9.0	28	2.67	1.02	1 - 5
Sunripe X EG	7.0	18	1.55	0.78	1 - 3
Sunripe X 7-3	9.5	21	3.80	1.80	1 - 7
Fla.5-15 OP	8.0	26	5.65	2.00	1 - 9
Fla.5-15 X EG	6.5	16	2.27	2.65	1 - 5
Fla.5-15 X 7-3	9.0	22	5.87	1.20	1 - 10
Fla.9-16 OP	10.0	29	3.68	2.50	1 - 9
Fla.9-16 X EG	7.5	37	1.32	0.62	1 - 4
Fla.9-16 X 7-3	10.0	50	3.12	1.70	1 - 8
Fla.5-14 OP	.	3	7.00	1.70	5 - 8
Fla.5-14 X EG	.	16	1.81	1.37	1 - 6
Fla.5-14 X 7-3	.	7	2.28	2.13	1 - 7
Fla.KE15 OP	10.0	19	1.84	0.89	1 - 3
Fla.KE15 X EG	7.5	16	1.50	0.63	1 - 3
Fla.KE15 X 7-3	10.0	22	4.77	2.34	1 - 9
Sunlite OP	7.0	35	1.68	1.13	1 - 6
Sunlite X EG	6.0	48	1.64	0.91	1 - 4
Sunlite X 7-3	8.5	31	5.19	2.08	1 - 10
Fla.9-12 OP	8.0	12	6.08	1.31	4 - 8
Fla.9-12 X EG	6.5	12	2.83	1.14	1 - 5
Fla.9-12 X 7-3	9.0	18	5.38	2.56	1 - 9
'EarliGrande'	5.0				
Fla.7-3	10.0				

z evaluated in the scale 1 to 10, being 10 the highest bud set
y bud set evaluated in 18 month-old seedlings
x EG= 'EarliGrande', OP= open-pollinated

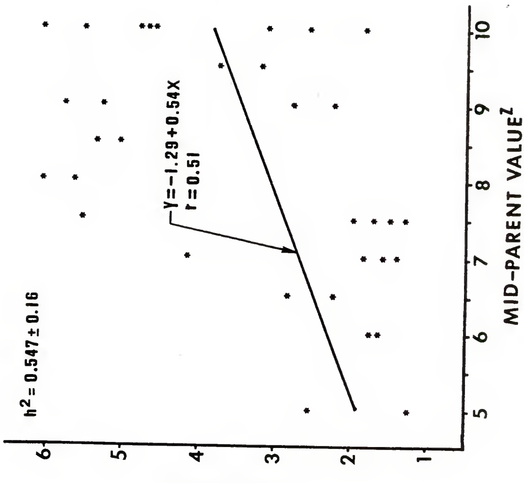
Table 4.3. Effect of pollen parent on flower bud set of their offspring.

Contrast	Flower bud set rating[z]	F value
'EarliGrande' vs Fla. 7-3	1.84 vs 4.05[y]	13.88**
Fla. 7-3 vs OP[x]	4.05 vs 3.44	26.39**
'EarliGrande' vs OP	1.84 vs 3.44	14.29**

z scale 1 to 10, being 10 the highest bud set.
y average of 12 families per cross or OP family.
x OP= open pollinated family.

FIGURE 4.1. Mid-parent offspring regression for flower bud set in some Florida low chill peach and nectarine families.

z scale used 1 to 10, with 10 being the highest bud set.


h2 = 0.547 ± 0.16
Y = -1.29 + 0.54X
r = 0.51
OFFSPRING
1
2
3
4
5
6
MID-PARENT VALUE^Z
5
6
7
8
9
10

SECTION V

THE HIGH DENSITY NURSERY SYSTEM (HDN) FOR BREEDING PEACH AND NECTARINE: A TEN YEAR ANALYSIS.

Introduction

Genetic advance in breeding of fruit tree species is limited because of the relatively long juvenile period and the size of the plant (HANSCHE, 1983). These 2 attributes hinder progress in breeding by imposing a limit to the number of plants that can be screened and by increasing the number of years that elapse before a breeding cycle can be completed. Response to selection (R), or genetic gain, is defined by the formula $R=iVph^2$. It is possible to obtain a higher genetic gain by applying a stronger selection pressure (i), when enough genetic variability is available to be exerted on (Vp). Response is dependent on the number of years required to complete a cycle of selection. Therefore, a better estimate of response is $Ry=Sh^2/n$, where Ry is response per year, S is selection differential, h^2 is the heritability of the trait and n is the number of years to complete a breeding cycle. Approaches to shortening the juvenile period include cultural practices which speed up the growth of the seedlings and enable them to attain a minimum sized plant earlier (ZIMMERMAN, 1972). Breeding for short juvenile period is another alternative for shortening the breeding cycle (VISSER 1964, 1976), but significant progress by this method may require several generations in some fruit crops mainly because the degree of selection intensity that can be applied is limited by the number of large plants that can be practically grown. Two approaches to increase the i factor are introducing dwarfing genes into the population under study (HANSCHE and BERES, 1980) and use of the HDN system for fruiting seedlings in the nursery (SHERMAN et al., 1973). It is the main objective of this study to make an evaluation of the HDN used by the University of Florida breeding program in the last 10 years and to determine its accuracy and feasibility for future use in breeding peaches and nectarines. The degree of success seen in the past 10 years should give an idea of advances in peach and nectarine over the next 10 years.

Materials and Methods

Seedlings evaluated in the HDN during the period 1975 to 1984 were used for the purposes of this study. Several traits were evaluated as follows:

Chilling requirement (CR) is presented as a rating in chilling units given to each seedling by using as reference the bud break of a selection or cultivar of known CR.

Crop load (CRO) was intended to serve as an indicator of yielding capacity. Values were assigned in the scale 1 to 10, little or no fruit set to the heaviest fruit set, respectively.

Fruit color (CO) was evaluated in the scale 1 to 10, from yellow with no red color to a complete red over color, respectively.

Fruit shape (SH) was rated also in the scale 1 to 10, with 10 for fruit that were round or slightly oblong with no suture bulge or deep sutures and the abscence of pronounced or acute tips.

Fruit firmness (FI) mainly covers uniformity of ripening but in addition includes overall firmness. This is a trait whose general rating depends on firmness of several parts of the fruit, such as tip, suture, and shoulder. A rating of 10 was applied to those fruits that were subjectively judged firm all over by the time of appearence of yellow ground color equivalent to commercial ripening.

Fruit weight (SIZ) was obtained by weighing a representative sample of commercially firm fruit and was stated in grams.

Fruit development period (FDP) was the number of days elapsed between 50% bloom and the first commercial harvest.

Daily gain was a generated variable, involving SIZ and FDP, and expressed as the ratio SIZ/FDP.

Every year (except 1980), a variable number (10 to 30) of selections were made from about 5000 hybrid seedlings (selection intensity usually greater than 0.4%) growing in the HDN. During the same year the selections made were budded to nematode tolerant rootstocks and planted in an adjacent block under commercial spacing and management. A minimun of 2 budded trees per selection were established in all cases.

Partial and multiple correlation analysis of data were made among traits and a regression analysis to estimate genetic gain was fitted to generation means (FALCONER, 1982). Analysis of variance components for the traits under study were obtained by using the model $Yijk = M + Ai + Bj + ABij + Eijk$ where A stands for the effects of genotypes ($i = 1,2,\ldots,12$), B,the effects of environment (years $j = 1, 2, 3$) and AB the genotype X year interaction that in this case was confounded with E (error) because of lack of replications (k) within years. In all cases statistical analyses were part of the Statistical Analysis System (SAS Institute, Cary, N. C.)

Results and Discussion

Repeatability of Several Traits for Peaches and Nectarines. Correlations between traits evaluated in the HDN (stage 1) and when the budded trees produced their first fruit (stage 2) are indicated in Table 5.1. High and positive correlations were found for CR, (0.624**), FDP (0.644**), and SIZ (0.522**), and intermediate but highly significant for CO (0.390**). Correlations were nonsignificant for SH, CRO and FI. When data were analyzed for correlation between stage 1 and the average of second and third year of fruiting in the field (stage 3), there was a slight increase for CR (0.624 vs 0.731) while FDP remained basically the same (0.641), color decreased slightly (0.390 vs 0.23), and SH, FI and CRO were again nonsignificant. The results indicate that evaluation for several traits can be made with reasonable accuracy in the fruiting nursery. This may be explained in part because those traits have high h^2 values, as reported in other crops and breeding populations (HANSCHE and BERES, 1966; HANSCHE et al. 1966, 1972, 1975; VILEILA-MORALES et al., 1981). When data were analyzed for correlations between stage 2 and average of second and third year of fruiting in the field (stage 3), the repeatability was greatly increased, as expected, and highly significant for all the traits evaluated (Table 5.1). This signifies that ratings on budded trees are consistent from year to year even though they are subjective in assignment.

Estimates of variance components (Table 5.2) obtained for a random sample of selections and cultivars during 1982, 1983 and 1984 indicate major genetic determination for most of the traits except for CRO and daily fruit gain. Chilling requirement is reported to be highly affected by enviromental fluctuations (HANSCHE et al., 1972); however the data covering the period from 1982 to 1984 show that the effect of years was not important on CR for this population sample. This may have been due to the fact that CR is evaluated in comparison to reference cultivars and in this way a more precise evaluation of bloom time and so CR is obtained. The same factors may affect the evaluation of FDP probably because this trait involves also CR completion as the beginning date. Fruit size has been reported to be little affected by yearly differences in climate (HANSCHE et al., 1972). Crop load is difficult to assess because of the many components that determine yield and large environmental effects on that trait. Daily gain (SIZ/FDP) involves a larger error term than other traits, probably because it is made up of 2 types of observations involving twice the error in evaluation and the genotype times year interaction.

If repeatability is low, more accuracy can be gained with repeated measurements. If it is high, little will be added with temporal replication of measurements (FALCONER, 1982). The latter could be the case for CR, FDP, SIZ, and CO between stage 1 and stage 2. The fact that some correlations between stages (H^2 broad sense) were nonsignificant or low may imply that the expression of those traits is not adequate in stage 1 as may be be the case for CRO. Younger trees in the fruiting nursery do not set fruit as well as older trees (FORDE, 1975) and under strong competition this effect could be even more pronounced. Also, FI and SH measurements are evaluated subjectively (as is CRO) and because they are composed of several quantitative traits such as presence of tip, shoulders, and suture for SH, and firmness at the tip, shoulders, and suture for FI, this may lead to greater errors in subjectivity in the evaluation of these traits. However, evaluation for these traits between stage 1 and stage 3 is more precise because more fruit is present on the trees permitting the breeder to more accurately judge those qualitative parameters.

Correlation coefficients reveal the relationship between randomly changing variables. The same variable in this case is evaluated at different stages but the meaning is the same. The fact that correlations for some variables were nonsignificant does not necessarily mean that the selection procedure is not efficient either in picking up the good genotypes or discarding those with low expectations. What may be indicated is that the range of the selected population has a limited span. A thorough assesment of the HDN would require the testing in stage 2 of all the seedlings originally planted in stage 1, both the ones that were promoted to stage 2 because of cultivar potential and those that were discarded from stage 1. This kind of test was not possible in the present study.

Differences in the Behavior of Traits Evaluated at Different Stages. There are trends in the expression of some traits when compared among stages. For instance, CR is usually higher in younger seedlings. Presumably this is because younger seedlings stop growth later in the fall and this affects the chilling accumulation process (300 units vs 279 units); therefore, they come out of dormancy later in the spring than adult plants. Fruit size is expected to increase in the older trees because of more nutrient availability in the mature, well spaced trees and because fruit is being borne on larger diameter twigs. Increased fruit size in budded trees is reflected in the data (83.9 g/fruit vs 91.5g/fruit). No change occurred for other traits between the HDN and budded trees (Table 5.3).

Correlations Among Traits. Table 5.4 shows the phenotypic correlations obtained for most of the selections made during the 1975 to 1984 period. The more interesting ones are underlined. A small but significant negative correlation between CR and FDP was found (-0.19 **). This result was expected, because under Gainesville, Fla., conditions, plants requiring higher amounts of chilling bloom later and therefore develop under higher temperatures as well as longer photoperiods. A high correlation (0.49 **) between SIZ and FDP was found, which indicates that the longer the fruit is on the tree the greater physiological potential for larger fruit size. Low but significant positive correlations were obtained between FDP and FI (0.12 **) and FDP and SH (0.20**). These were expected because later ripening peaches are generally firmer and ship better than earlier ripening ones and earlier ripening peaches tend to have poorer shape. Shape and FI have a similar low correlation (0.12 *). It was unexpected that a significant correlation existed between SH and CO (0.26 **). It may be that when fruit shape is good the fruit are allowed to stay on the tree longer (since the fruit lack sutures or tips which have a tendency to become soft) thus having a longer time (1 or 2 days) during which more color develops.

Genetic Advance in the HDN. One major goal of this program is to breed for early ripening peaches and nectarines. Therefore, the analysis of the information for gain in SIZ and FDP was limited to those peaches and nectarines that ripen between 60 and 90 days after blooming.

When peaches and nectarines were considered together, the best fit for the data relating fruit weight with selection year was given by a quadratic regression equation, $Y=54.72 +9.49X -0.78X^2$. When peaches and nectarines were analyzed separately (Figure 5.1), the best fit for the nectarine data was given by a linear regression of the form, $Y= 63.52 + 2.16 X$, where X= years (from 1 to 8). This represents a genetic gain of 2.2 g per year in the 1976 to 1984 period. The trend for peaches was different in that the equation that best explained the trend in SIZ was of a quadratic nature, $Y = 51.99X +14.22X-1.36X^2$; this behavior may be explained by the fact that selections made in 1984 were earlier than in any other year during the period examined. Many of the selections made in 1984 were a product of embryo rescue from early maturing seed parents. An analysis of FDP showed that the trend has been to decrease the number of days required for fruit maturation. An equation fitted to the data indicates this situation, $Y=67.0+4.09X-0.46X^2$. On the other hand, if 1984 is excluded from the peach data, a linear regression model is better fitted to the data, $Y=65.67+3.66X$. The slope of the linear model indicates that a gain of 3.7 g per year was obtained. The relationship found between FDP and

SIZ (Table 5.4) indicates that the earlier the ripening the smaller the fruit size. Fortunately this relationship is not due to a linkage of genes but is physiological in nature. It is clearly evident that good progress can be obtained in SIZ in breeding peaches and nectarines with a shorter FDP.

Analysis of SIZ and FDP on the basis of daily gain (SIZ/FDP) was an attempt to eliminate the influence of FDP on fruit size. However the results (data not included) gave the same trends as the ones indicated for fruit size alone.

Other Traits. An evaluation for traits such as CO, SH, and FI indicates little change during the period examined (Figure 5.2 and 5.3). The biggest variations occurred for CO and SH for both peaches and nectarines. In the last 3 years the ratings given to the selected peaches and nectarines seemed to have been established at a high level for most of the traits. Variations in earlier years may have been due to more emphasis in 1 or 2 traits that needed more improvement than others, for instance larger SIZ and shorter FDP. Larger rates of advancement on some traits have probably not been made because they are already in the upper levels of improvement and less genetic variation exists.

Table 5.1. Phenotypic correlations between traits evaluated in the high density nursery (stage 1), during their first year under commercial spacing (stage 2) and with an average of second and third year under commercial spacing (stage 3).

	STAGE		
Characteristic	1^z vs 2	2^y vs 3	1 vs 3^x
Chilling requirement	0.624**	0.863**	0.731**
Fruit development period	0.644**	0.915**	0.641**
Crop load	-0.095n.s.	0.489**	0.180n.s.
Fruit color	0.390**	0.752**	0.230n.s.
Fruit size	0.522**	0.888**	0.817**
Fruit shape	0.114n.s.	0.632**	0.284n.s.
Fruit firmness	-0.16n.s.	0.808**	0.119n.s.

z, y, x number of clones evaluated =72, 34 and 33, respectively
n.s.,** = nonsignificant and significant at P=0.01, respectively

Table 5.2. Estimates of variance components for CR, FDP, CRO, CO, SH, FI, and daily gain in peaches and nectarines, evaluated during the period 1982 - 1984.

Variance component	d. f.	Chilling requirement	%	Fruit dev. period	%	Crop load	%	Fruit color	%
Year	2	696.96	6.5	14.48	7.7	0.081	0.9	0.54	11.8
Genotypes	10	9178.03	86.9	158.44	84.3	0.918	12.4	1.93	42.4
Error	20	685.60		14.42		7.312		2.087	

Table 5.2. continued.

Variance component	d.f	Fruit size	%	Fruit shape	%	Fruit firmness	%	Daily^z gain	%
Year	2	166.71	34.1	0.133	6.4	-0.027	0	0.039	51.9
Genotypes	10	156.77	32.1	0.642	31.0	1.90	78.8	0.012	15.8
Error^y	20	164.49		1.290		0.512		0.024	

evaluation made on two budded trees per selection, under commercial spacing (stage 3).

z daily gain= fruit size/days for fruit development.

y error term contains year X genotype interaction.

Table 5.3. Mean values for traits evaluated in the high density nursery (stage 1), first year under commercial spacing (stage 2) and an average for second and third year under commercial spacing (stage 3), for selected clones of peach and nectarine.

Characteristic	Mean value + S D		
	Stage 1^z	Stage 2^y	Stage 3^x
Chilling requirement	300.00+ 76.79	279.16+87.71	286.58+82.30
Fruit development period (days)	84.95+13.09	87.80+13.09	84.63+12.76
Crop load^w	7.11+1.96	7.33+2.29	7.15+1.69
Fruit color^w	7.69+1.91	7.68+2.23	7.96+1.68
Fruit size(g)	83.97+20.53	91.06+24.69	91.51+17.38
Fruit shape^w	7.55+1.23	7.27+1.48	7.63+1.34
Fruit firmness^w	9.06+0.89	8.11+1.37	8.72+1.28

z, y, x number of clones evaluated = 72, 34 and 33 respectively.
w rated on the scale of 1 to 10.

Table 5.4. Correlation matrix among characteristics representing Florida germplasm for peach and nectarine.^{z}

No.	Trait	2	3	4	5	6	7
1	Chilling requirement	-0.19 **	-0.01	0.08	0.05	-0.05	-0.002
2	Fruit dev. period		0.02	0.08	0.49 **	0.20 **	0.12 *
3	Crop load			0.20 **	-0.08	0.03	0.02
4	Fruit color				-0.21 **	0.26 **	0.13 **
5	Fruit size					0.07	0.14 **
6	Fruit shape						0.12 *
7	Fruit firmness						

z number of paired observations = 389.

*, ** = significant at P=0.05 and P=0.01 respectively.

FIGURE 5.1. Yearly selection means for fruit size on selected peach and nectarine with a 60 to 90 days fruit development period.

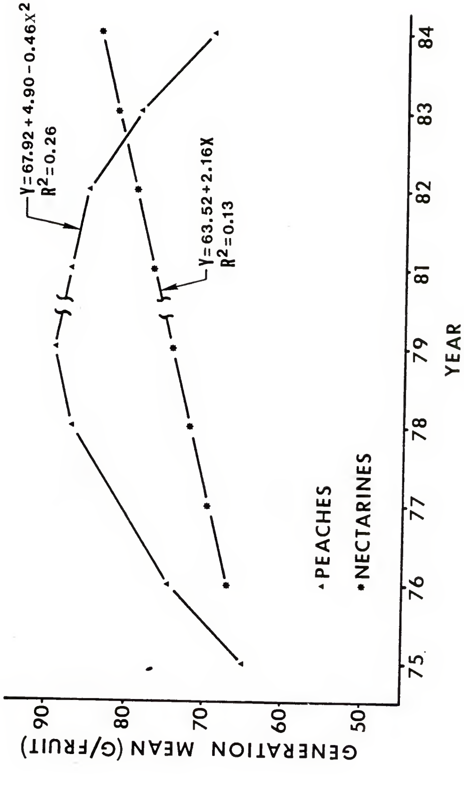

GENERATION MEAN (G/FRUIT)
90
80
70
60
50
75
76
77
78
79
81
82
83
84
YEAR
Y=67.92+4.90−0.46X²
R²=0.26
Y=63.52+2.16X
R²=0.13
PEACHES
NECTARINES

FIGURE 5.2. Means for several traits in peaches selected each year in the high density nursery.

z scale used 1 to 10, being 10 the best rating.

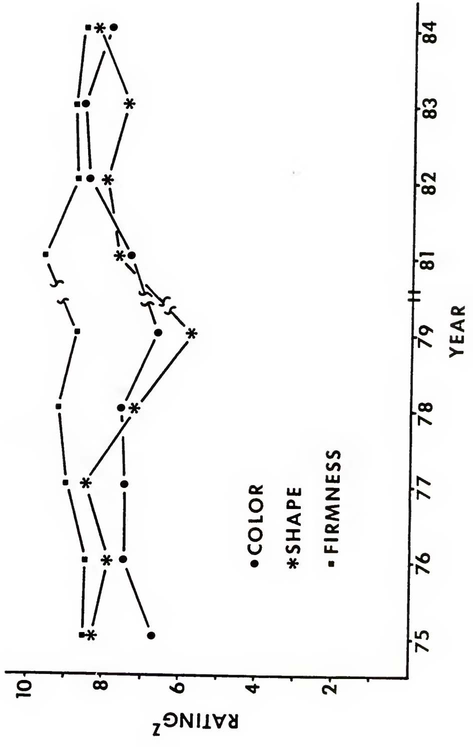
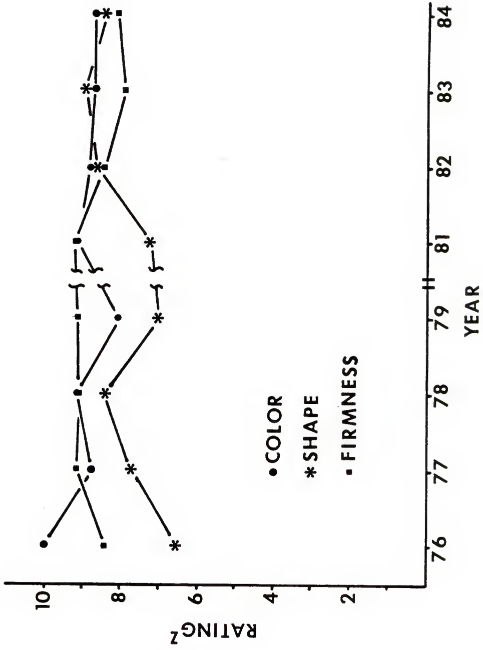

RATING^Z
10
8
6
4
2
75
76
77
78
79
81
82
83
84
YEAR
●COLOR
✱SHAPE
▪FIRMNESS

FIGURE 5.3. Yearly selection means for several traits in nectarines selected in the high density nursery.
z scale used 1 to 10, being 10 the best rating.


RATING^{z}
10
8
6
4
2
76
77
78
79
81
82
83
84
YEAR
● COLOR
* SHAPE
▪ FIRMNESS

SECTION VI

SUMMARY AND CONCLUSIONS

Selection for bud chilling requirement on the basis of the seed chilling requirement for germination is difficult to assess when the range of chilling requirements of the parents is narrow (less than 300 units). The correlation obtained (0.206 **) and observations in the field support this statement. Attempts to improve the correlation between seed and seedling chilling requirement by removing the seed coat were not satisfactory. Seeds with the seed coat present gave a better correlation than those without it, even though the time of stratification was reduced slightly by removal of the seed coat. The role of the seed coat in germination appears to be more of a physical nature than a chemical one.

It may be possible to speed up the breeding process by using heavy bud setters as parents in crossing peaches and nectarines. Heavy bud setters produced precocious progeny with higher bud set than parents with low bud set. The heritability for flower bud set ($h^2 = 0.547$) in 2 year-old seedlings is high enough to allow rapid progress in breeding for precociousness and heavy bud set.

Evaluation of traits such as chilling requirement, fruit development period, fruit size, and fruit color in the HDN showed a high repeatability when compared to the first bearing of budded trees under commercial spacing. More reliable estimates can be obtained by evaluation of those traits in stage 2 and stage 3; however, the amount of improvement in the heritability value would not be compensated by the extra time and cost to evaluate the seedlings one more year.

Early ripening, large sized fruit of peaches and nectarines are a main goal of this breeding program. Progress in increasing fruit size for nectarines from 1976 to 1984 amounted 2.2 g/yr. The progress before 1984 in peaches was quite good, with a gain of 3.7 g/yr as indicated by the slope of a linear regression fitted to the data. Peach selections showed a decline in fruit size during 1984, probably as a result of earlier maturing selections coming out of embryo rescue from early maturing seed parents. A positive correlation between FDP and SIZ was obtained for this breeding population (0.497**).

Traits such as fruit color, firmness, and shape showed little change during the 1975 to 1984 period. However, in the last 3 selection years peaches and nectarines were selected that possess higher ratings for all of those traits. In general, the ratings for all of the traits in peaches and nectarines selected in the HDN are above 8 (in a scale where 1 = least desirable and 10 = most desirable).

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He is married to the former Ofelia Garcia and has three children: Georgina 11, Luis 9, and Roxana 3.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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